

# Broccoli

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**Scientific Name and Introduction:** *Brassica oleracea* L., Italica group, also known as broccoli, calabrese or sprouting broccoli, is a native of southern Europe. The crop is annual and grows to maturity in about 75 to 95 days, depending on cultivar, season and planting date. The whole immature inflorescence (head) is the edible portion, with the floret tissue most often being consumed. It grows best in cool climates and is available year-round from many areas of North America, although a large proportion is grown in California.

**Quality Characteristics and Criteria:** High quality broccoli has either a dark or bright green color with closed beads, i.e., flower buds. The head should be firm to hand pressure, compact, and the stalk cleanly cut to the appropriate length for a particular grade standard or for crowns.

**Horticultural Maturity Indices:** Head diameter, compactness and all beads on the head being closed. Over-mature heads are characterized by open flower buds or enlarged buds on the verge of opening resulting in a loose head.

**Grades, Sizes and Packaging:** There are three grades, U.S. Fancy, U.S. No. 1 and U.S. No. 2. They are based on external appearance, damage, trimming and stalk diameter (USDA-AMS, 1943). In the fresh market, broccoli is normally bunched, with two to three heads bound together. These are packed 14 to 18 bunches in waxed cardboard boxes, weighing approximately 10 kg (21 lb) (Boyette et al., 1996). Larger heads may have the stem trimmed off to produce “crowns” and these are packed loose in 9 kg (20 lb) boxes. Individual florets are also cut and packed in 2.5 to 5 kg (5.5 and 11 lb) film bags for hotel, restaurant and institutional use.

**Pre-Cooling Conditions:** Field-packed broccoli is commonly cooled by injecting liquid-ice into the waxed cartons (Cantwell and Suslow, 1999). Ice maintains the proper temperature and RH for transport and distribution. Hydro-cooling and forced-air cooling are also options, but good temperature management is required during transport (Cantwell and Suslow, 1999).

**Optimum Storage Conditions:** The recommended conditions for commercial storage are 0 °C (32 °F) with 98 to 100% RH. Under these conditions, broccoli can be kept in excellent condition for 2 to 3 weeks. Use of package icing is required if storage or transport conditions cannot be maintained at the recommended temperature or RH (Shewfelt et al., 1983). If temperature can be maintained, the use of ice is not necessary (Kleiber et al., 1993). The use of perforated plastic film packaging to minimize wilting is also recommended (Toivonen, 1997). Loss of quality during prolonged storage is a result of wilting, yellowing of buds and leaves, loosening or opening of buds, and decay.

**Controlled Atmosphere (CA) Considerations:** The recommended atmospheres for broccoli are between 1 to 2% O<sub>2</sub> + 5 to 10% CO<sub>2</sub> when storage temperature is 0 to 5 °C (32 to 41 °F) (Makhlouf et al., 1989; Cantwell and Suslow, 1999). Optimal CA conditions can double storage-life, especially when held above optimum temperatures. However, if O<sub>2</sub> drops < 1% in storage, there is a risk of off-odors, caused by the generation of sulfur-containing volatiles (Forney et al., 1991). High rates of air exchange are recommended in shipping containers to avoid accumulation of off-odors. Modified atmosphere packaging systems generally maintain both O<sub>2</sub> and CO<sub>2</sub> at 10% to prevent the accumulation of the off-odors.

**Retail Outlet Display Considerations:** Bottom-icing of the refrigerated display will enhance shelf-life of broccoli (Perrin and Gaye, 1986). Misting of the refrigerated display will also enhance shelf-life and quality retention for broccoli (Barth et al., 1992).

**Chilling Sensitivity:** Broccoli is not sensitive to chilling temperatures and should be stored as cold as possible without freezing.

**Ethylene Production and Sensitivity:** Broccoli has a very low ethylene production rate at  $< 0.1 \mu\text{L kg}^{-1} \text{h}^{-1}$  at 20 °C (68 °F). Broccoli is extremely sensitive to ethylene, with floret yellowing being the most prevalent symptom. Exposure to ethylene at  $2 \mu\text{L L}^{-1}$  at 10 °C (50 °F) results in a 50% reduction in shelf-life (Cantwell and Suslow, 1999).

**Respiration Rates:**

Temperature	mg CO <sub>2</sub> kg <sup>-1</sup> h <sup>-1</sup>
0 °C	20 to 22
5 °C	32 to 36
10 °C	76 to 86
15 °C	160 to 180
20 °C	280 to 320

Respiration rates for cut florets are slightly higher (Izumi et al., 1996). To get mL kg<sup>-1</sup> h<sup>-1</sup>, divide the mg kg<sup>-1</sup> h<sup>-1</sup> rate by 2.0 at 0 °C (32 °F), 1.9 at 10 °C (50 °F), and 1.8 at 20 °C (68 °F). To calculate heat production, multiply mg kg<sup>-1</sup> h<sup>-1</sup> by 220 to get BTU per ton per day or by 61 to get kcal per metric ton per day. Data are from Cantwell and Suslow (1999).

**Physiological Disorders:** Bead yellowing may occur in over-mature broccoli, when stored at higher than optimal temperatures, and/or in response to exposure to ethylene. Presence of yellow beads ends the commercial marketability of broccoli. There sometimes is confusion between senescence-associated yellow bead and yellow-light green marginal areas of floret that occur due to shading by adjacent floret tissue. This is normal for tissue that is not exposed to light during head growth (Cantwell and Suslow, 1999). A disorder called black speck on stems occurs in stored broccoli and certain cultivars are more resistant than others (DeEll and Toivonen, 1998).

**Postharvest Pathology:** Grey mold rot (*Botrytis cinerea* Pers.:Fr.) is the most commonly reported mold in shipped broccoli (Ceponis et al. 1987). *Erwinia carotovora* (Jones) Bergey et al. and *Pseudomonas* spp. bacterial head rots are found on shipped and stored broccoli. Injury to the bead tissue during handling may enhance development of these rots (Liao and Wells 1987). While *Erwinia carotovora* decay seldom develops at temperatures  $< 5 \text{ °C}$  (41 °F), decay caused by *Pseudomonas* spp. can be severe (Liao and Wells, 1987) since it grows relatively well even at low storage temperatures (Brocklehurst and Lund, 1981). A few cultivars of broccoli have been identified with some resistance to *Pseudomonas* spp. (Canaday et al., 1991).

**Quarantine Issues:** None.

**Suitability as Fresh-cut Product:** Broccoli is commonly converted to fresh-cut floret products. Stems are also shredded into a packaged coleslaw-type product.

**Special Considerations:** Some cultivars have greater storage-life potential than others (Cantwell and Suslow, 1999). If long distance shipping or storage is integral to a marketing strategy, then consideration should be made for appropriate cultivar selection, especially if controlled atmospheres are not being used.

Freezing injury may occur during liquid-ice cooling if excessive salt is used in the slurry mixture or if the broccoli is stored below -1 °C (30.2 °F). Thawed buds will be very dark and translucent and can later turn brown or may serve as sites for development of bacterial decay. Rough handling during harvest and packing can damage floret tissue and can lead to increased levels of decay. Hot-water dips have recently been shown to improve shelf-life of broccoli (Forney, 1995).

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